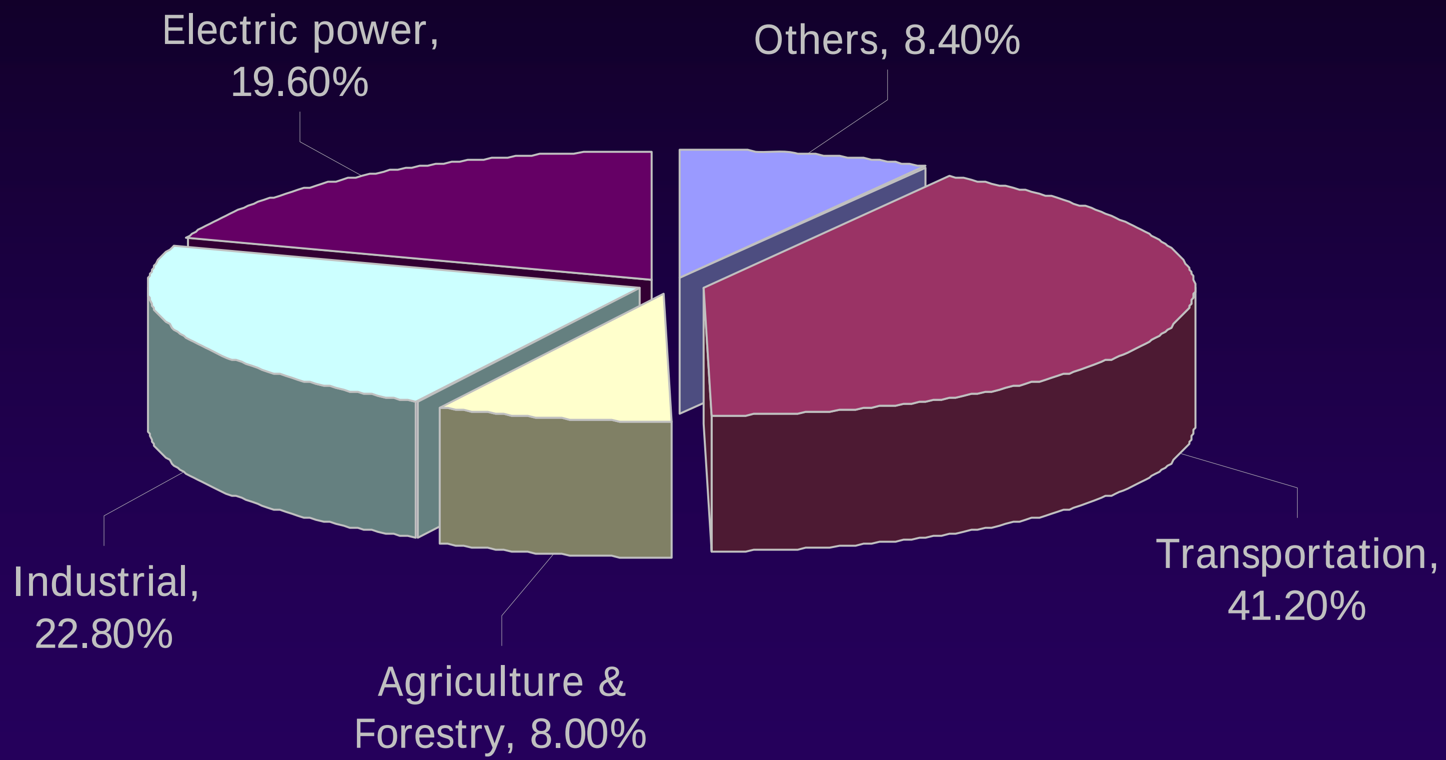
The Role of Agriculture in Mitigating Greenhouse Gas Emissions

Johan Six

UC DAVIS PLANT SCIENCES

Source of greenhouse gases in CA

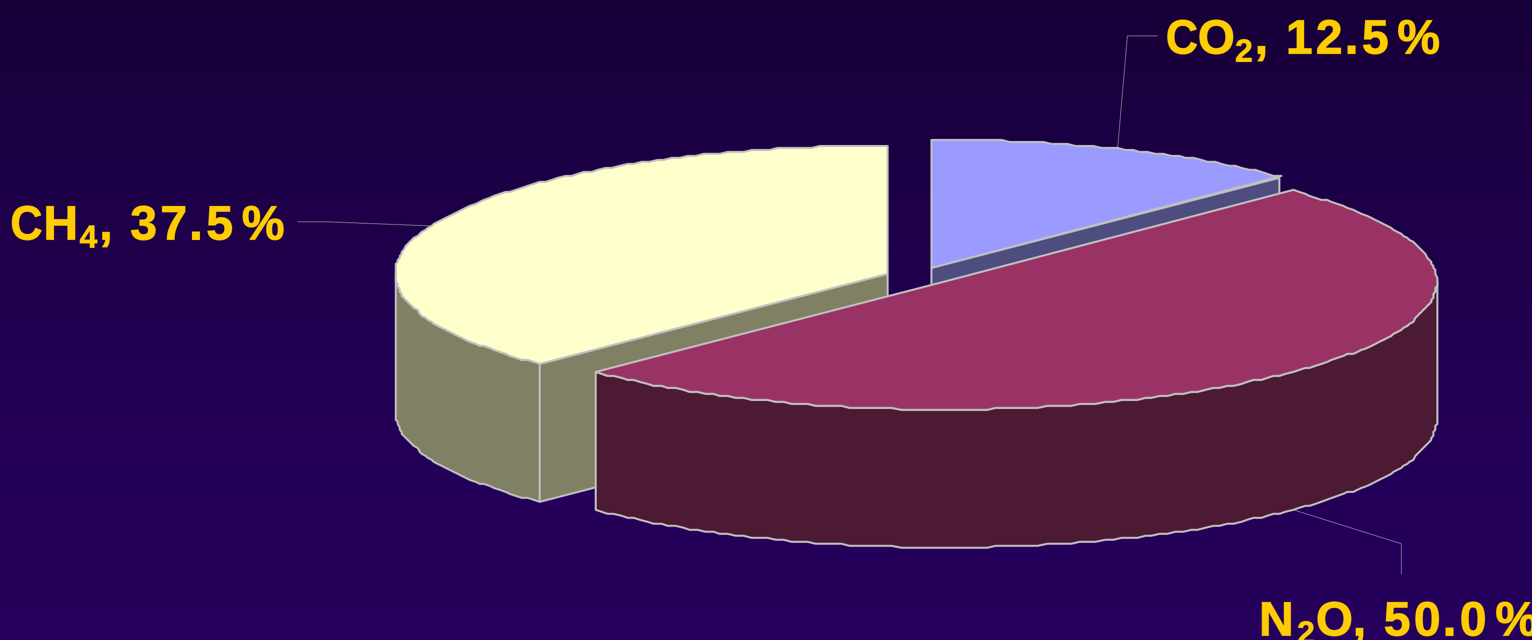


California Energy Commission, 2005

Composition and sources of greenhouse gases by agriculture

Sources: Fossil fuels, biomass burning, soil degradation

Sources: Livestock, manure, anaerobic soils (rice)



Sources: Fertilizer, crop residues, manure

California Energy Commission, 2005

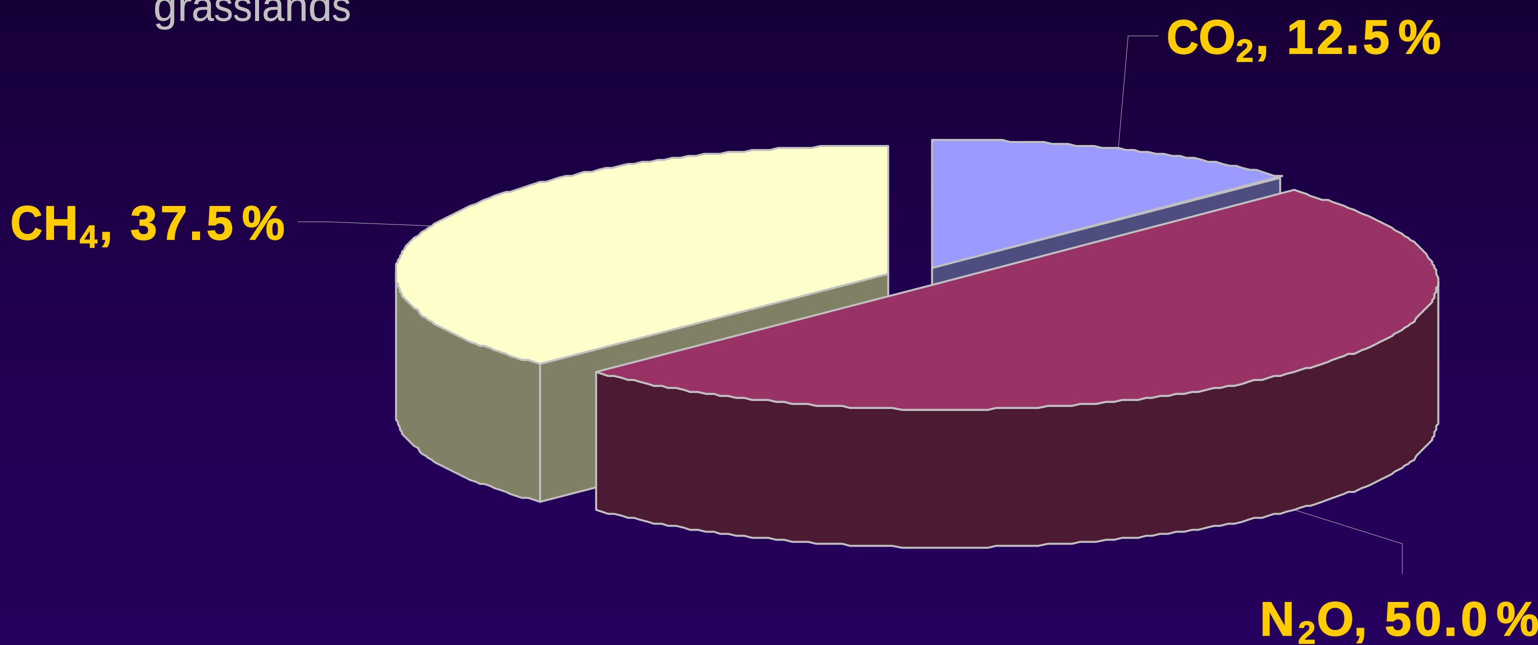
Composition and sinks of greenhouse gases by agriculture

Sources: Livestock, manure, anaerobic soils (rice)

Sinks: Aerobic soils, especially forests and grasslands

Sources: Fossil fuels, biomass burning, soil degradation

Sinks: Buildup soil organic matter and plant biomass



Sources: Fertilizer, crop residues, manure

Sinks: No sinks in soils

California Energy Commission, 2005

Practices for GHG mitigation

- Reduced or zero tillage
- Set-asides/conversions to perennial grass
- Winter cover crops
- More hay in crop rotations
- Higher residue (above- & below-ground) yielding crops
- Manure application and organic cropping
- Reducing fertilizer application rate

Research question:

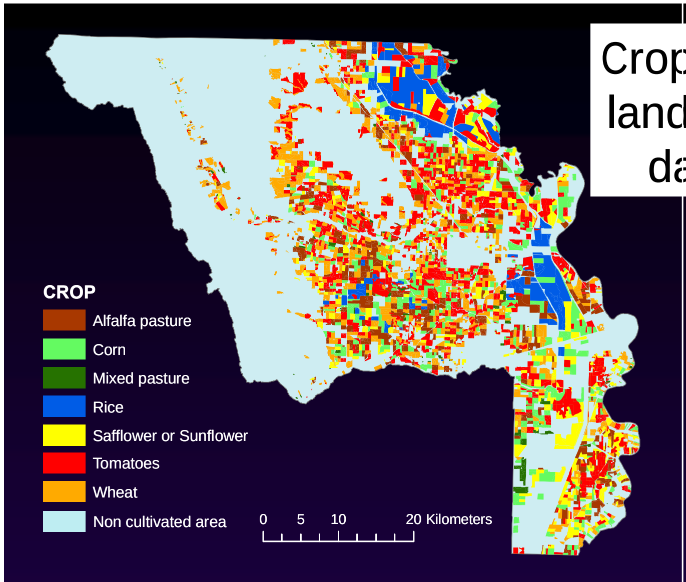
What is the potential for GHG mitigation by agriculture by changing practices for common crops and crop rotations in CA

= emissions under alternative practices – emissions under conventional practices

Assessing GHG emissions

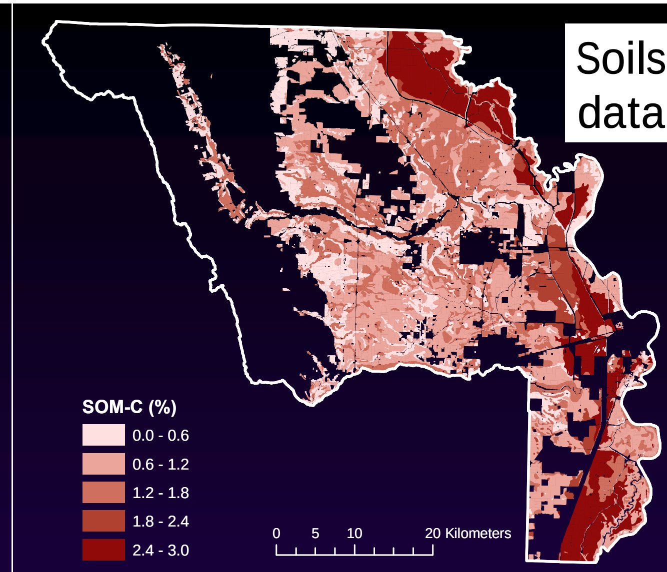
- Integrating measurements with modeling
  - Measurements for calibration and validation of model
  - Modeling for regional extrapolation and prediction in a cost-effective way
  - Measurements to monitor and further validate model
- Integrating remote sensing
  - To assess temporal and spatial variability in crop growth and production

Crop and land-use data



data from 1997, from DWR (Department of Water Resources)

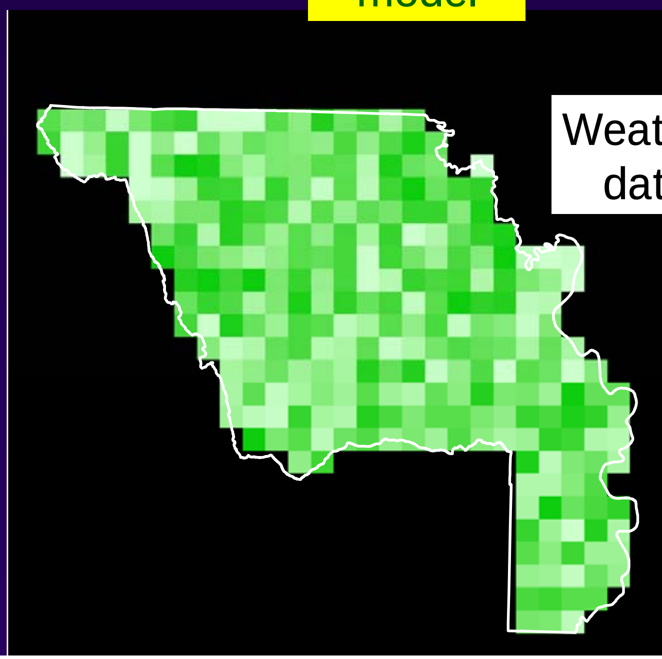
Soils data



from SSURGO (Soil Survey Geographic Database)

DAYCENT ⟷ Regional model

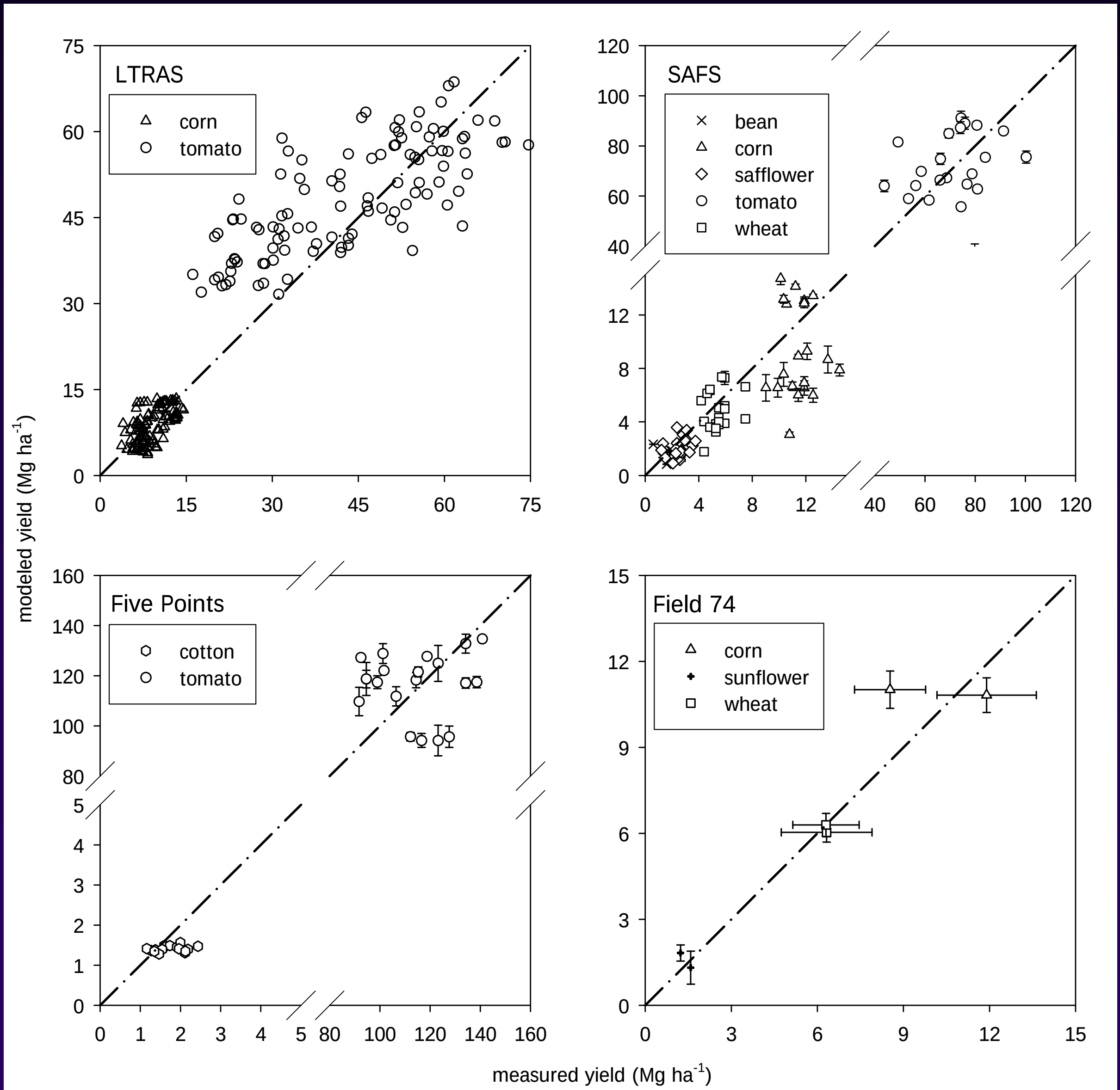
Weather data



3 x 3 km grid from DAYMET (University of Montana)

Validation: yields (Site)

Site level



Validation: yield and soil C (Site)

		LTRAS	SAFS	Five Points	Field 74
		prediction of yield			
variation explained by model (%)		86	92	94	92
partitioning of the MSD	non-unity slope (%)	13	4	3	5
	lack of correlation (%)	74	96	96	91
	square bias (%)	13	0	1	4
		prediction of soil organic carbon			
variation explained by model (%)		69	83	87	6
partitioning of the MSD	non-unity slope (%)	24	21	63	28
	lack of correlation (%)	70	56	31	45
	square bias (%)	6	23	6	27

Results (Site)

Site	Treatment or property	ΔSOC kg C ha^{-1} yr^{-1}	N_2O kg N ha^{-1} yr^{-1}	CH_4 kg C ha^{-1} yr^{-1}	GWP kg CO_2-eq ha^{-1} yr^{-1}
LTRAS	Standard tillage	95 ± 46[c]	3.18 ± 0.10	-1.52 ± 0.02	1081 ± 192
	Standard tillage and cover cropping	315 ± 46	2.60 ± 0.10	-1.44 ± 0.02	9 ± 192
	Standard tillage and organic	1324 ± 46	3.02 ± 0.10	-1.49 ± 0.02	-3496 ± 192
	Proportion of variation due to seasonal differences[d]	*74%*	*37%*	*46%*	*72%*
	Conservation tillage	47 ± 87	3.01 ± 0.18	-1.51 ± 0.05	1182 ± 391
	Conservation tillage and cover cropping	321 ± 87	2.21 ± 0.18	-1.46 ± 0.05	-192 ± 391
	Conservation tillage and organic	1279 ± 87	2.98 ± 0.18	-1.49 ± 0.05	-3349 ± 391
	Proportion of variation due to seasonal differences	*65%*	*53%*	*68%*	*61%*

Results (Site)

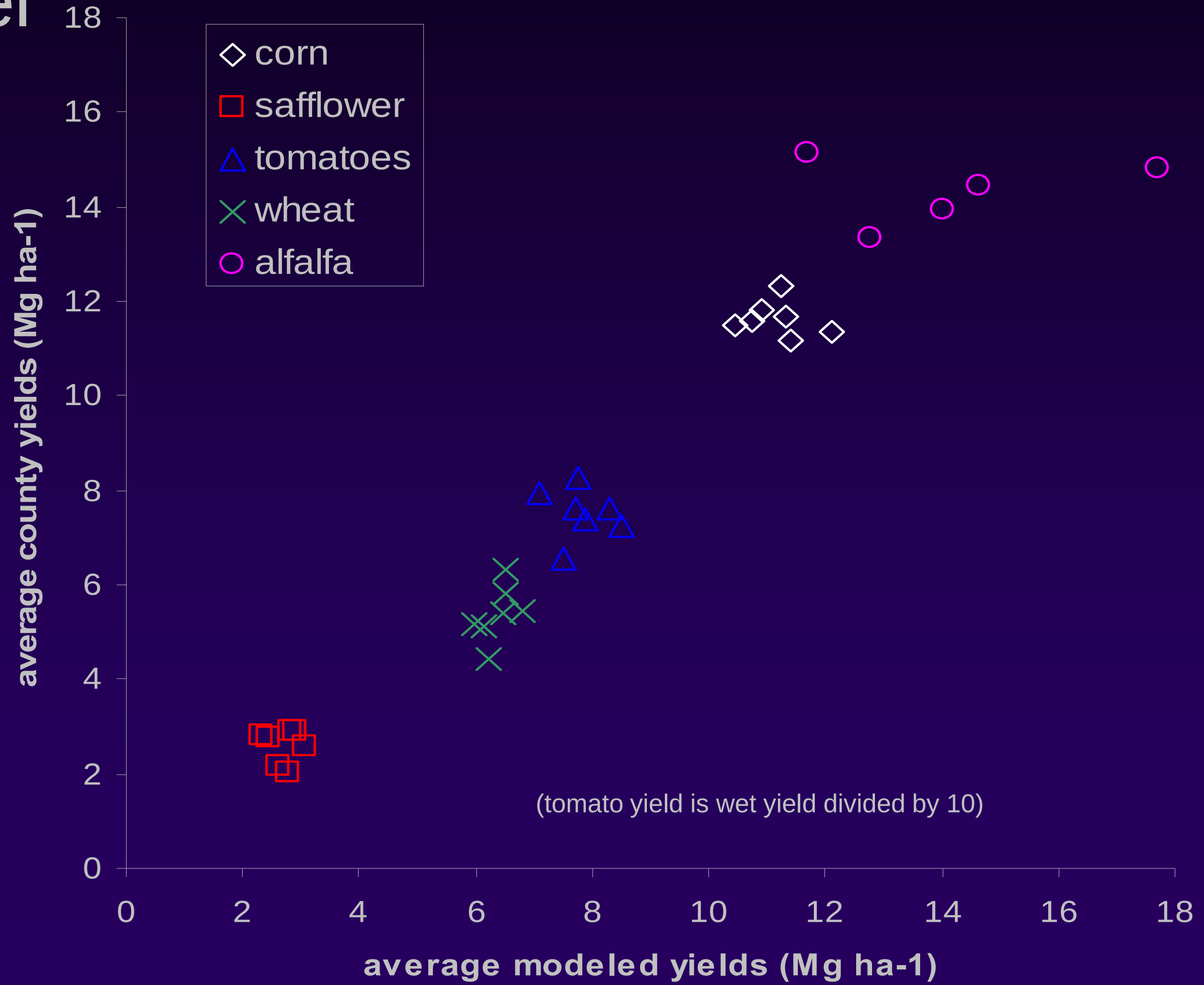
SAFS	Conventional 4-year rotation	407 ± 77	2.21 ± 0.08	-1.62 ± 0.02	-515 ± 292
	Conventional 2-year rotation	436 ± 78	1.54 ± 0.08	-1.44 ± 0.02	-925 ± 298
	Cover cropping	999 ± 77	1.70 ± 0.08	-1.63 ± 0.02	-2921 ± 292
	Proportion of variation due to seasonal differences	*94%*	*80%*	*89%*	*96%*
WSREC	Standard tillage	-90 ± 38	3.44 ± 0.10	-2.00 ± 0.02	1866 ± 147
	Standard tillage and cover cropping	677 ± 38	4.01 ± 0.10	-1.93 ± 0.02	-675 ± 147
	Conservation tillage	-9 ± 38	3.26 ± 0.10	-1.99 ± 0.02	1487 ± 147
	Conservation tillage and cover cropping	729 ± 38	3.79 ± 0.10	-1.94 ± 0.02	-969 ± 147
	Proportion of variation due to seasonal differences	*91%*	*82%*	*38%*	*92%*
Field 74	Standard tillage	128 ± 20	2.62 ± 0.08	-1.54 ± 0.04	700 ± 87
	Conservation tillage	256 ± 20	2.43 ± 0.08	-1.33 ± 0.04	150 ± 87
	Proportion of variation due to seasonal differences	*51%*	*49%*	*19%*	*43%*

Results (Site)

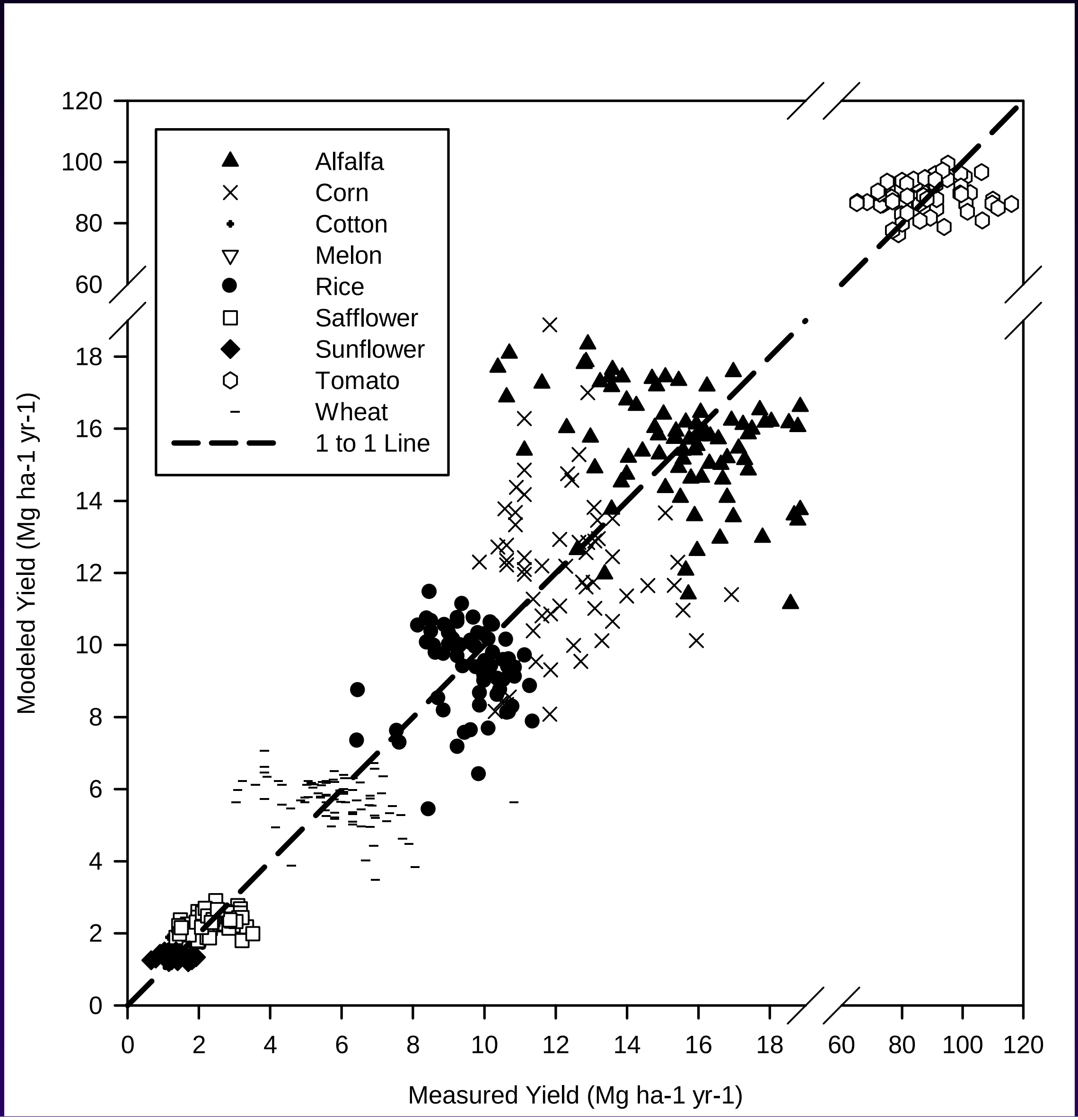
Site	Effect of treatment	ΔSOC[a] kg C ha^{-1} yr^{-1}	ΔN_2O[b] kg N ha^{-1} yr^{-1}	ΔCH_4[b] kg C ha^{-1} yr^{-1}	ΔGWP[b] kg CO_2-eq ha^{-1} yr^{-1}	Contribution of ΔN2O to ΔGWP
LTRAS	Conservation tillage	36 ± 31	-0.07 ± 0.08	0.00 ± 0.01	-168 ± 131	20%
	Cover cropping[c]	220 ± 65	-0.58 ± 0.14	0.09 ± 0.03	-1072 ± 272	25%
	Manure application[c]	1229 ± 65	-0.16 ± 0.14	0.04 ± 0.03	-4577 ± 272	2%
SAFS	Cover cropping	577 ± 21	-0.18 ± 0.02	-0.10 ± 0.01	-2201 ± 82	4%
WSREC	Conservation tillage	66 ± 10	-0.20 ± 0.03	0.00 ± 0.01	-336 ± 47	28%
	Cover cropping	752 ± 10	0.55 ± 0.03	0.06 ± 0.01	-2499 ± 47	-10%
Field 74	Conservation tillage	128 ± 28	-0.19 ± 0.11	0.20 ± 0.05	-550 ± 123	16%

Validation: yields (Regional)

Regional level



Validation: yields (Regional)



Results (regional)

Tillage	Fertilizer	Cover crop	GWP (Mg CO_2-eq ha^{-1} yr^{-1})		? SOC (kg C ha^{-1} yr^{-1})		N_2O (kg N ha^{-1} yr^{-1})	
			Sacramento Valley					
convent.	mineral, 75%	no	-0.89	± 0.76	-2	± 16	-1.92	± 1.59
conserv.	mineral	no	-0.68	± 0.36	103	± 34	-0.64	± 0.56
convent.	mineral	yes	-1.36	± 0.89	310	± 180	-0.48	± 0.94
conserv.	mineral	yes	-1.37	± 0.88	312	± 178	-0.48	± 0.94
convent.	Organic	no	-1.16	± 0.78	158	± 63	-1.23	± 1.51
conserv.	Organic	no	-1.94	± 1.03	288	± 88	-1.89	± 1.86
convent.	Organic	yes	-2.60	± 1.87	405	± 212	-2.38	± 2.81
conserv.	Organic	yes	-3.29	± 2.07	532	± 246	-2.86	± 2.98
			San Joaquin Valley					
convent.	mineral, 75%	no	-0.61	± 0.58	-4	± 14	-1.33	± 1.24
conserv.	mineral	no	-0.57	± 0.33	81	± 35	-0.59	± 0.55
convent.	mineral	yes	-1.35	± 1.07	284	± 170	-0.66	± 1.36
conserv.	mineral	yes	-1.38	± 1.08	287	± 169	-0.68	± 1.39
convent.	Organic	no	-0.49	± 0.89	154	± 54	0.16	± 1.96
conserv.	Organic	no	-1.14	± 0.90	255	± 79	-0.43	± 1.82
convent.	Organic	yes	-1.87	± 1.41	395	± 203	-0.89	± 2.41
conserv.	Organic	yes	-2.45	± 1.52	498	± 235	-1.32	± 2.41

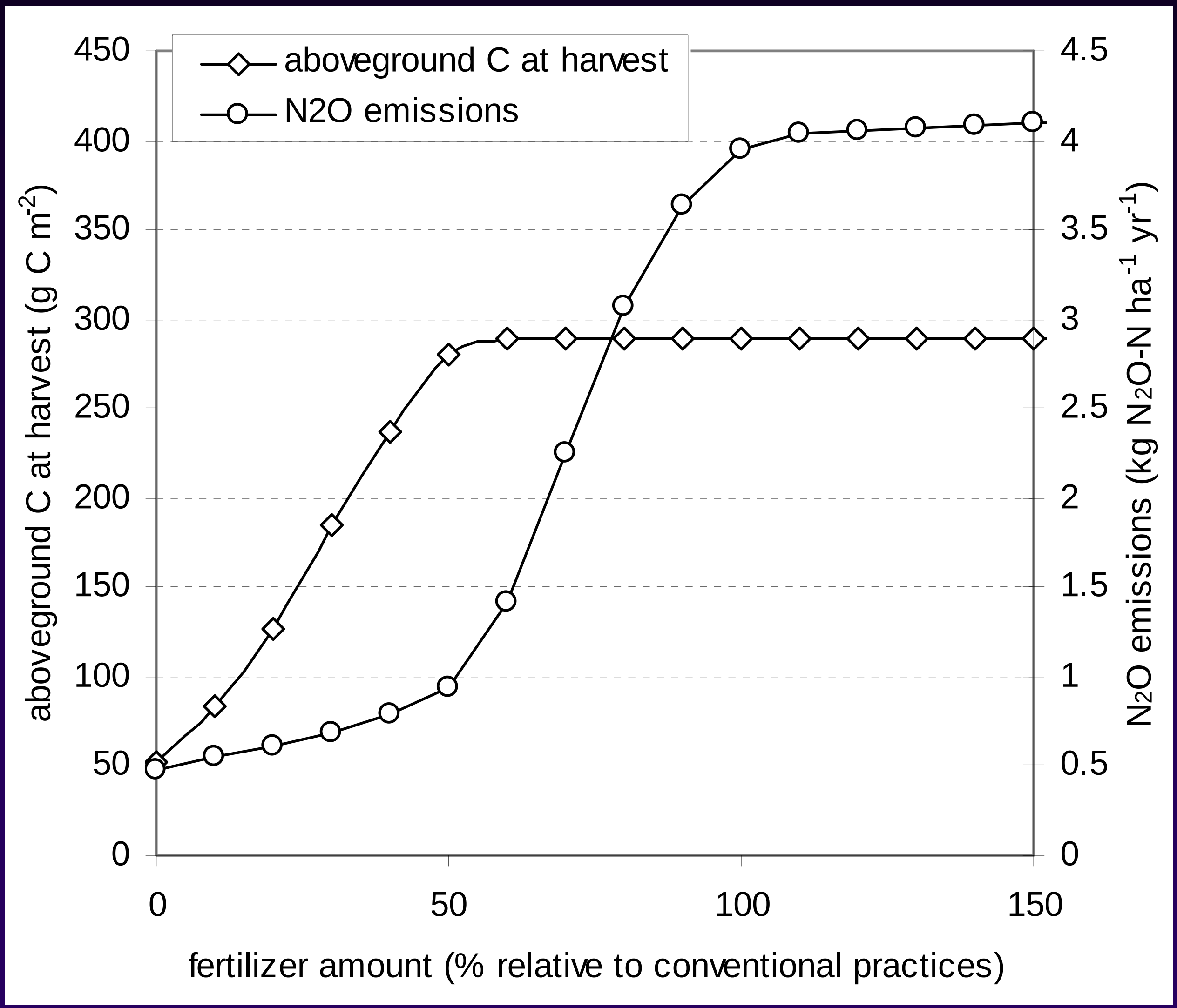
3 concerns around C-sequestration

- Permanence
  - They have to be secured over the long run
- Additionality
  - Carbon stocks with project activities compared to carbon stocks without project activities
- Leakage
  - Potential negative C flows due to the project (on land outside of the project) must be addressed
    - Migration of people who were farming on the land to other places and clearing forest somewhere else

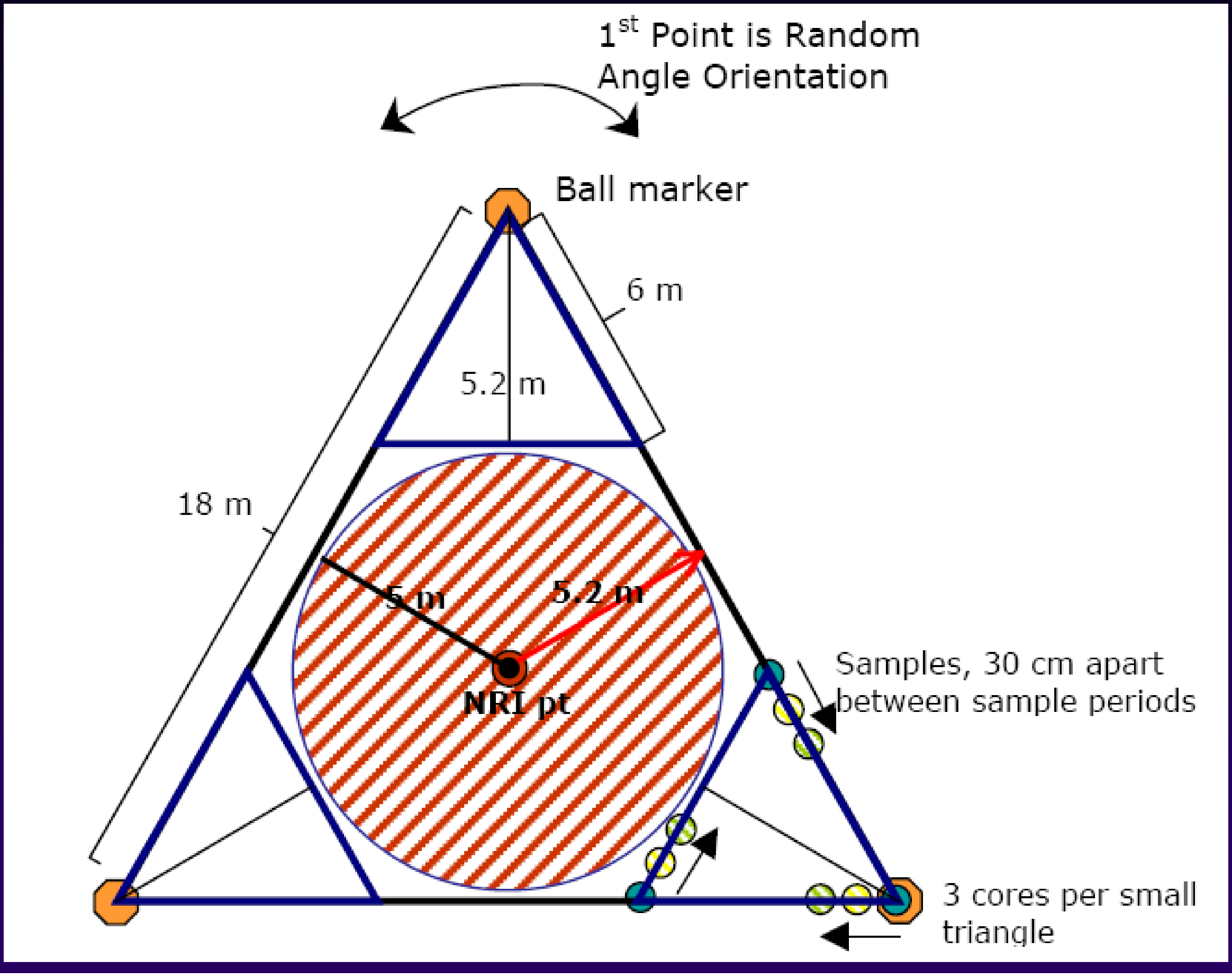
Future needs

- Get a handle on nitrous oxide
- Monitoring
- Decision support tool for stakeholders
  - COMET-VR

N2O ~ crop growth

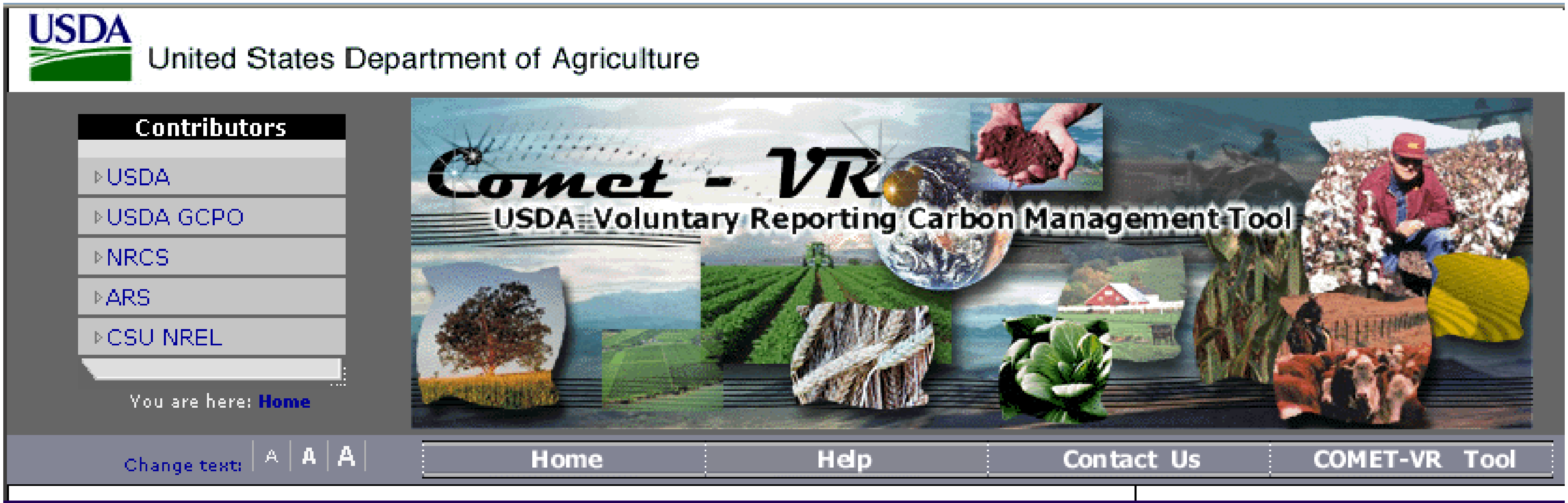


Monitoring



1st Point is Random
Angle Orientation
Ball marker
6 m
5.2 m
18 m
5 m
5.2 m
NRI pt
Samples, 30 cm apart
between sample periods
3 cores per small
triangle

COMET-VR (CarbOn Management and Evaluation Tool – Voluntary Reporting)



- Currently supports soil C change estimates and fuel usage
- N_2O emissions will be incorporated in the next version
- Perennial systems need to be optimized

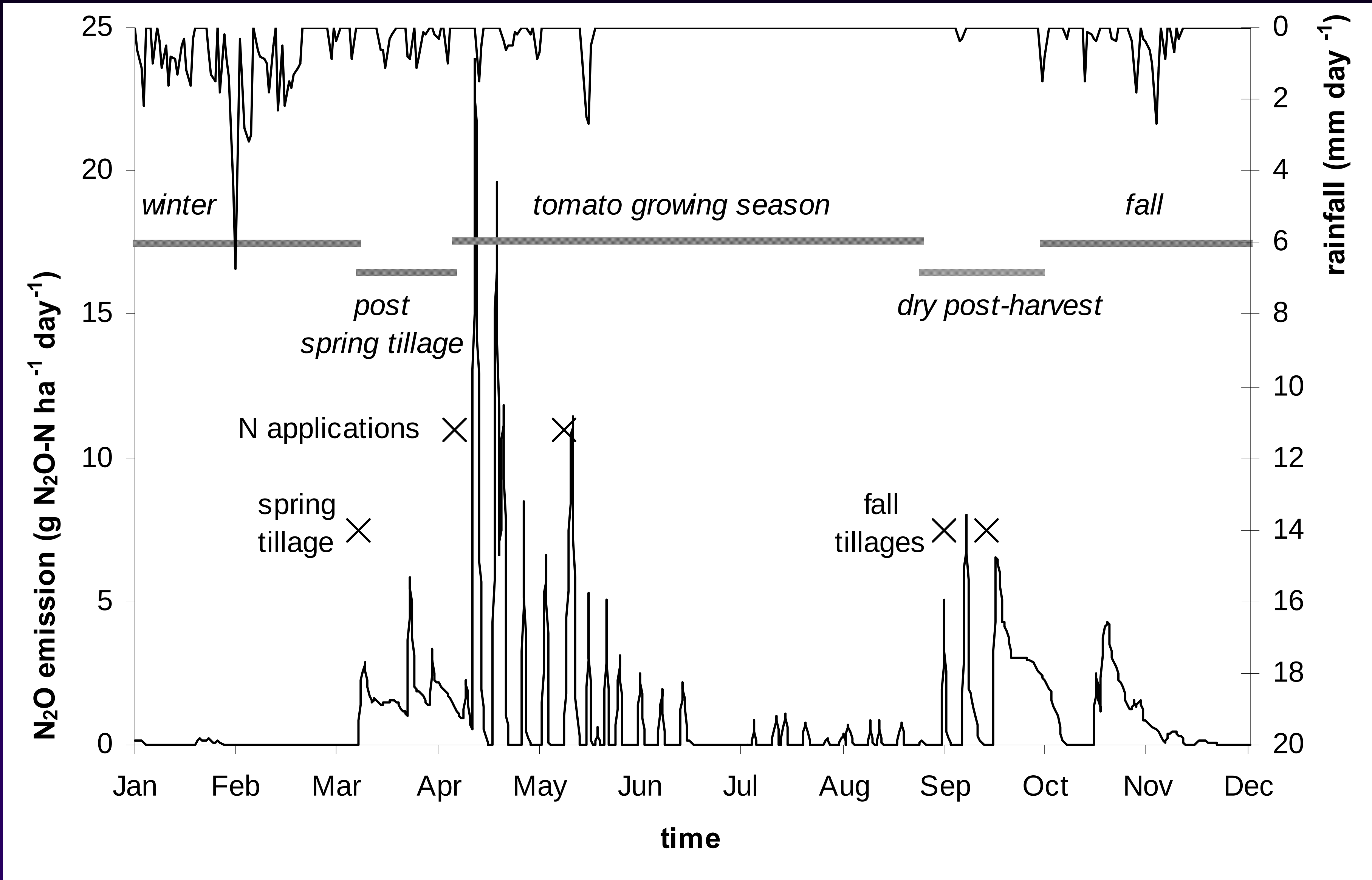
THANKS!

De Gryze et al. 2009. Modeling shows that alternative soil management can decrease greenhouse gases. Cal. Ag. 63:84-90.

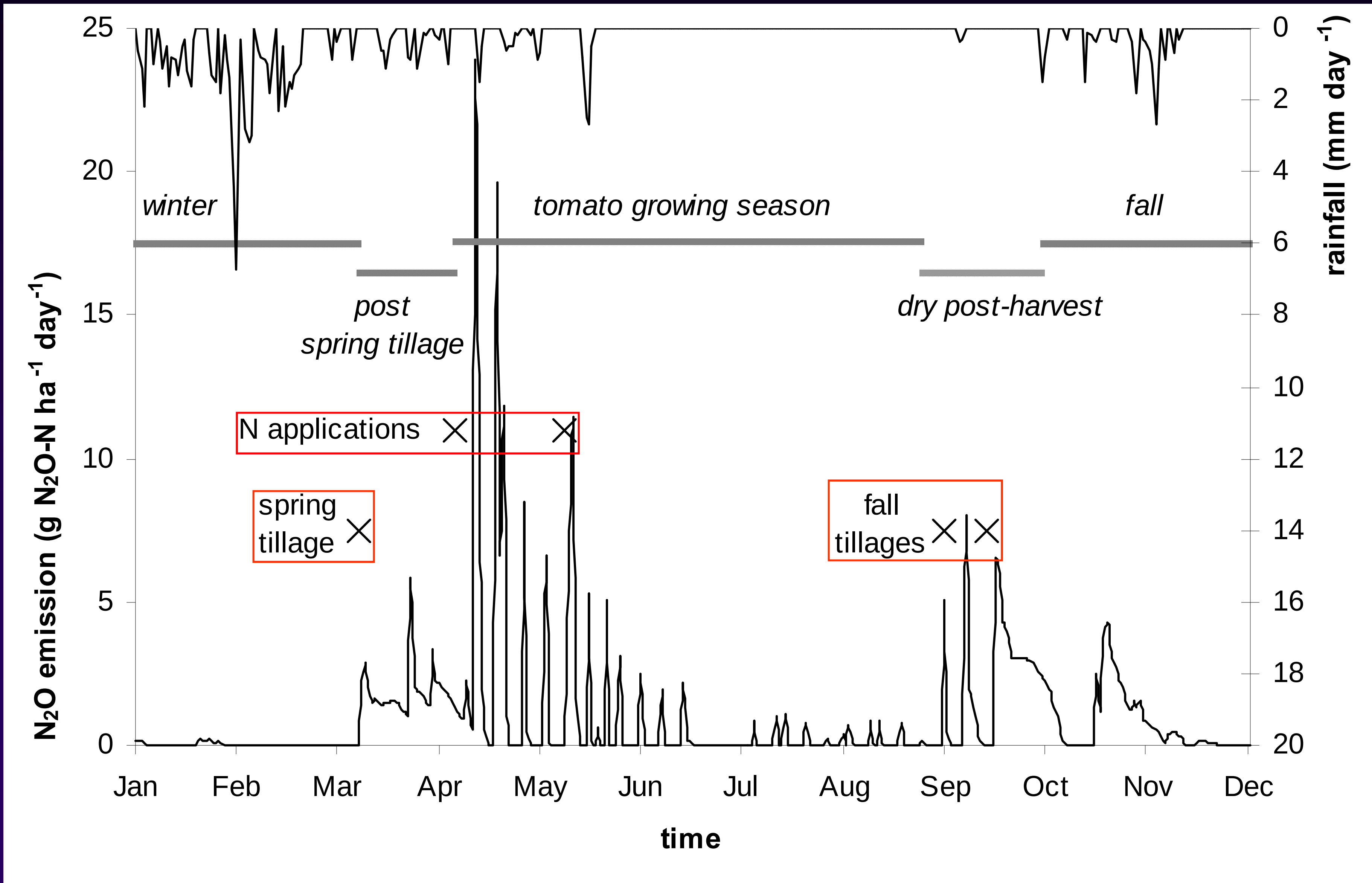
Howitt et al. 2009. Realistic payments could encourage farmers to adopt practices that sequester carbon. Cal. Ag. 63:91-95.

http://calag.ucop.edu/0902AMJ/toc.html

N_2O: variability!



N_2O: targeted measures



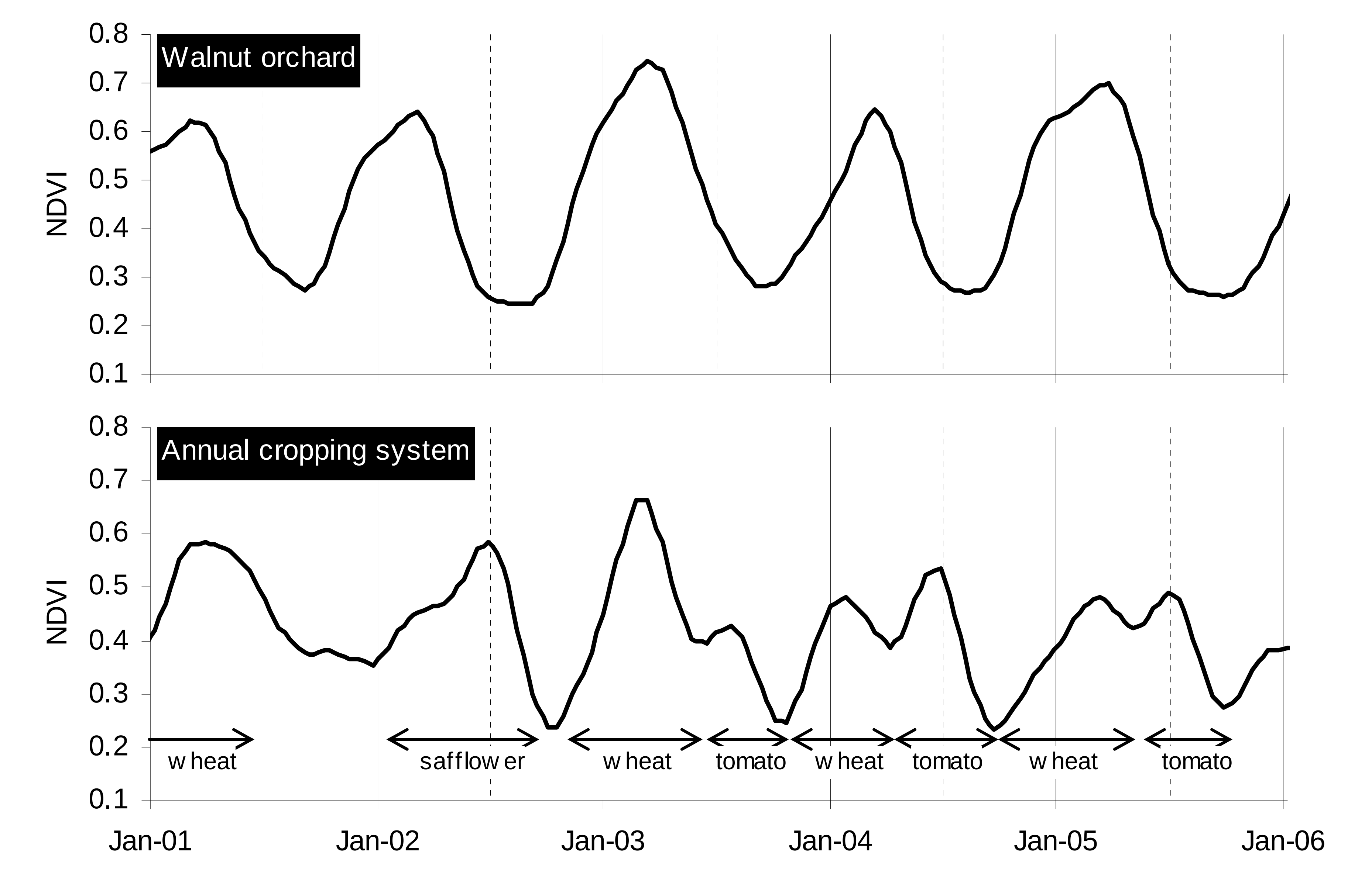
Perrenial crops!

area rank	crop	area (1000 acres)	economical value ($million)	economical rank
1	hay (mainly alfalfa)	1550	1141	6
2	nuts (almonds, walnuts and pistachios)	900	3454	1
3	grapes	800	3166	2
4	cotton	657	625	11
5	rice	526	408	13
6	intensely cropped vegetables (lettuce, broccoli, carrots, celery and peppers)	496	2920	3
7	wheat	369	104	>15
8	fruit trees (oranges, plums, lemon, peaches)	359	1292	5
9	tomatoes	307	942	9
10	corn	110	52	>15

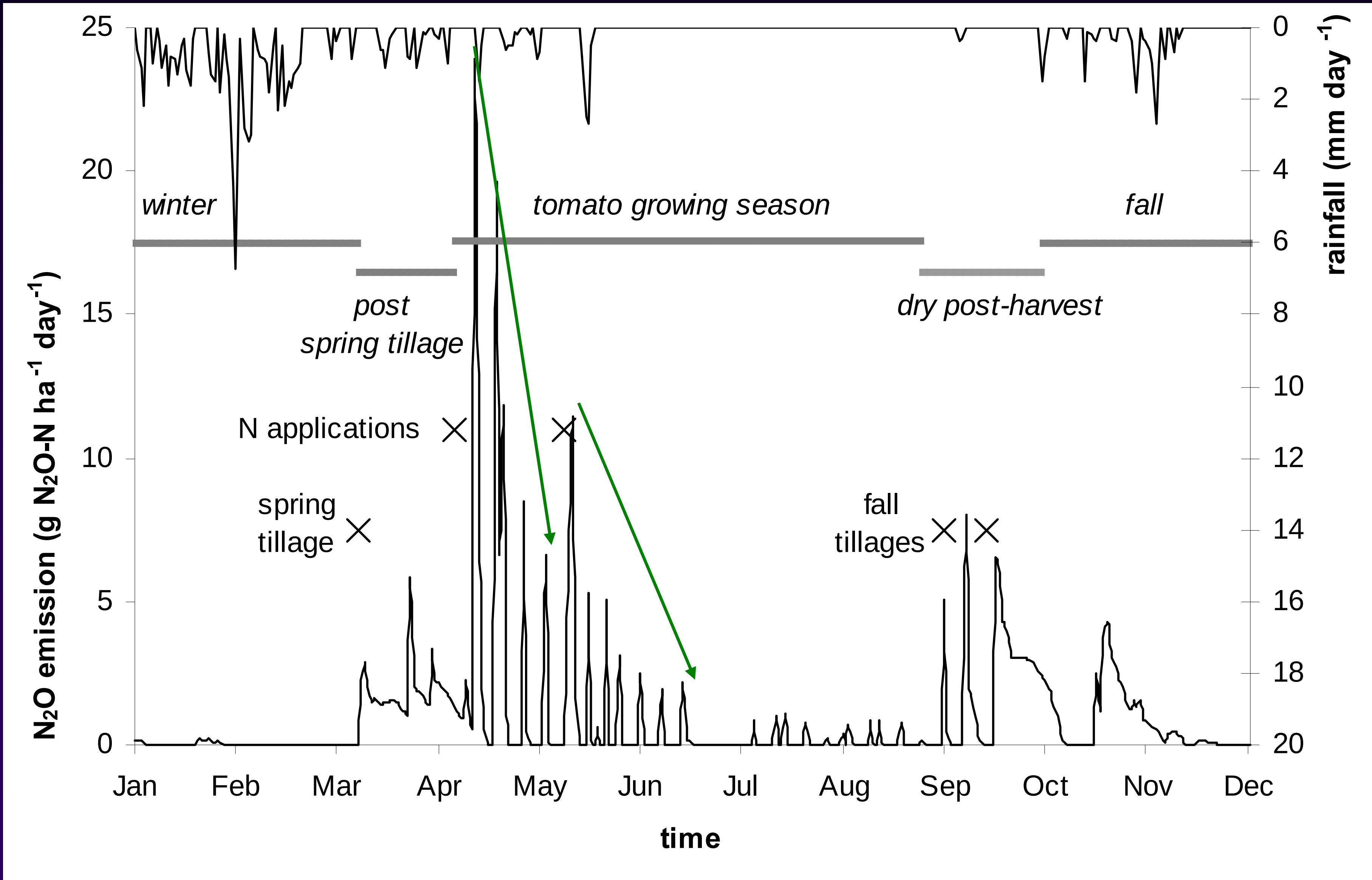
N_2O?

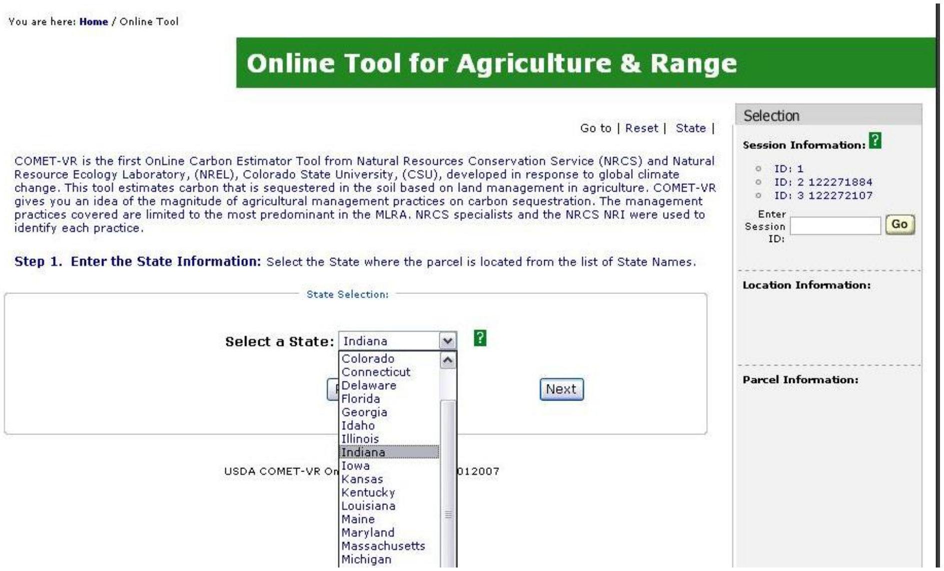
cropping system	nr observations in literature
alfalfa	4
nut orchards	0
vineyards	0
cotton	5
rice	78
intensely cropped vegetables	29
wheat	77
fruit orchards	0
tomato	6
corn	157

Remote sensing of crop growth

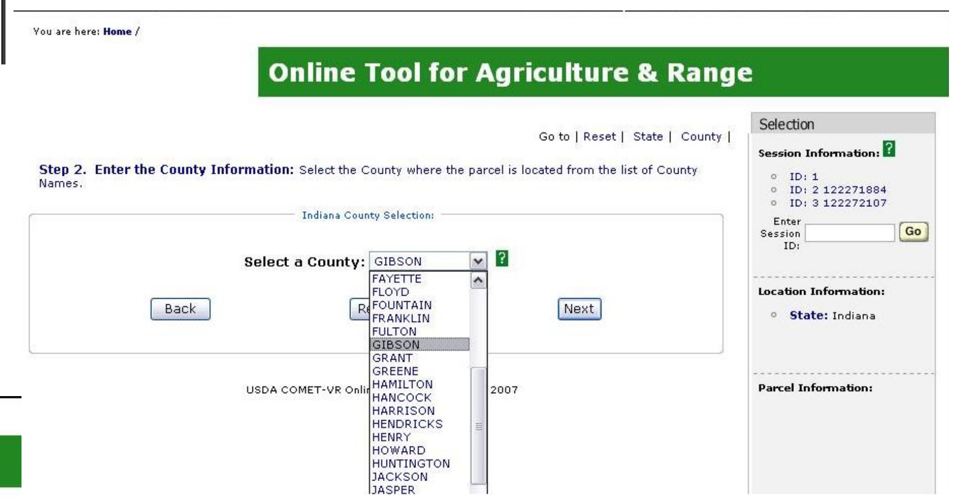


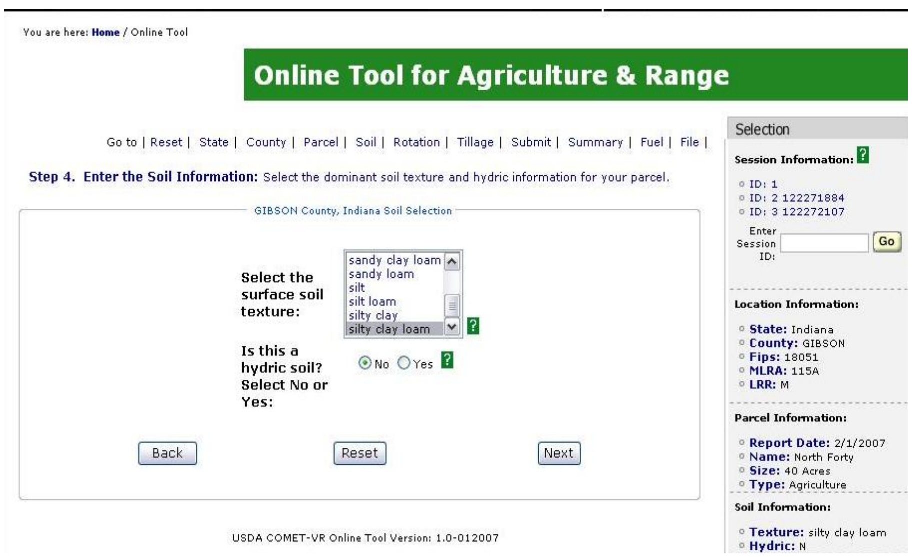
N_2O: variability!



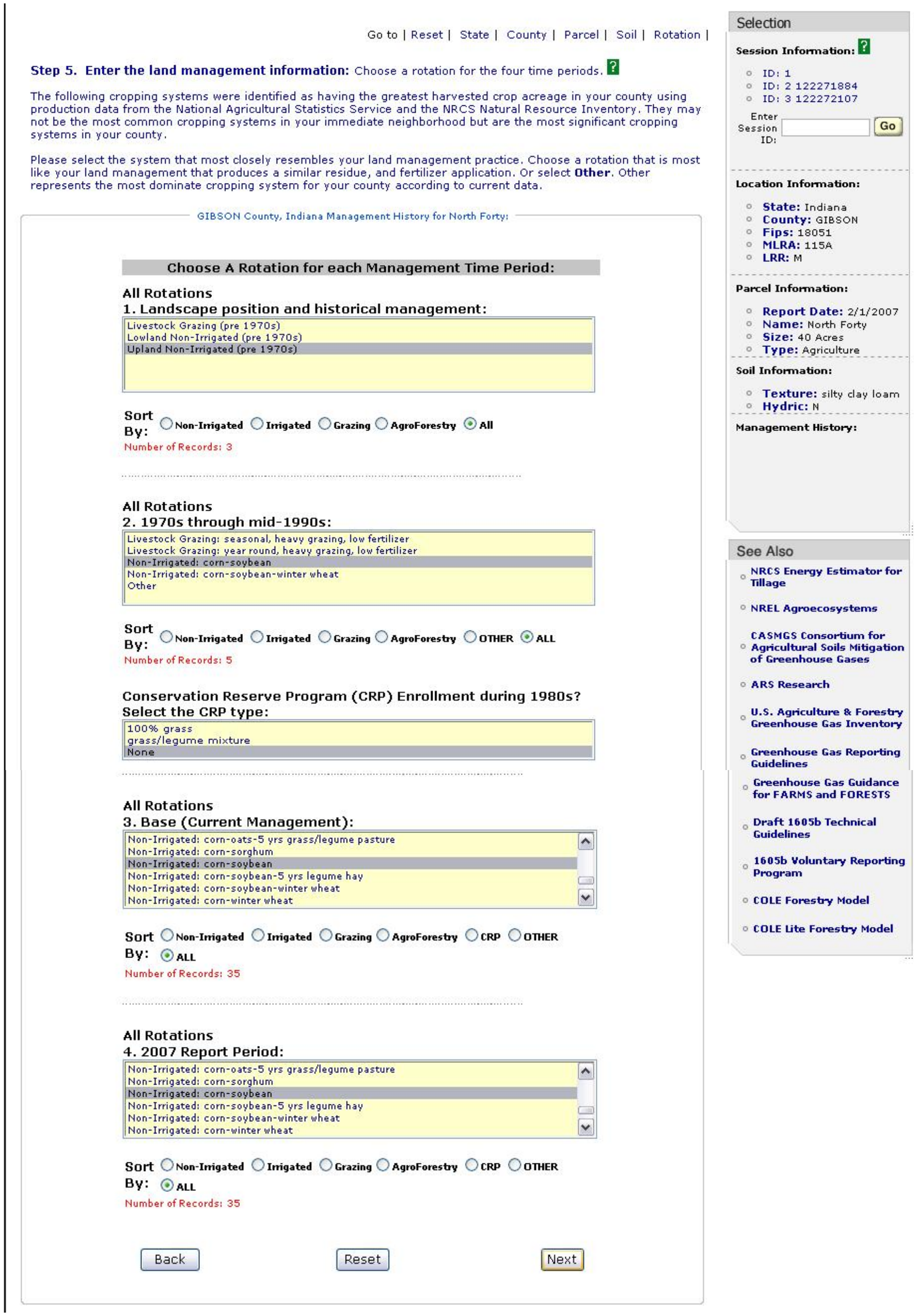


Select state and county



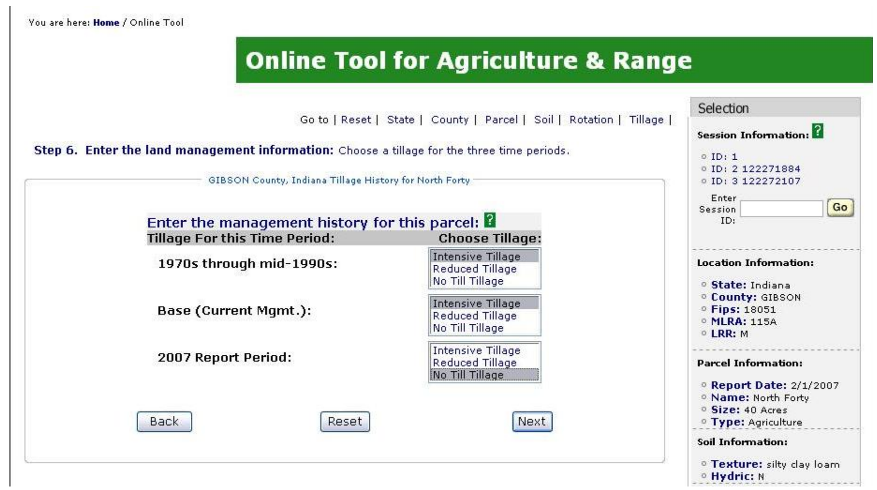


Select soil type and drainage condition



Select management sequences

Select tillage management sequence



GIBSON County, Indiana Century's Dynamic Carbon Database COMET-VR Summary:

Voluntary Reporting
Carbon Management Tool COMET-VR
Carbon Storage Report ?
Report Year: 2007
ID: 589453228

Parcel Description

Parcel Type:	Agriculture
Total Parcels for this Entity:	1
Parcel Name:	Parcel 1
Parcel Size:	100 Hectares
Location:	GIBSON, Indiana
Soil:	Non-hydric silty clay loam

Parcel Management History

Historic:	Upland Non-Irrigated (pre 1970s)
70s to 90s:	Non-Irrigated: corn-soybean; Intensive Tillage
Current:	Non-Irrigated: corn-soybean; Intensive Tillage
Report Period:	Non-Irrigated: corn-soybean; No Till Tillage

Predicted Change in Soil Carbon for the Parcel

Annual Change for 2007

	Carbon Change	Uncertainty ?		
		Avg Percent	Lower Bounds CI*	Upper Bounds CI*
Total Tonnes Carbon per year:	**39.39**	**0.00 %**	13.67	20.08
Total Tonnes CO2 Equivalent per year:	**144.32**	**0.00 %**	22.33	50.07

Values recorded in Metric units. One **tonne** of carbon is equivalent to 3.664 **tonnes** of carbon dioxide.

Please report the **Large Bolded Values** on your 1605B report for carbon change and uncertainty. We are 95% confident that your actual carbon change value is within (+-) 100 % of the modeled carbon change value shown on this report.

Location Information:

- **State:** Indiana
- **County:** GIBSON
- **Fips:** 18051
- **MLRA:** 115A
- **LRR:** M

Parcel Information:

- **Report Date:** 2/15/2007
- **Name:** Parcel 1
- **Size:** 100 Hectares
- **Type:** Agriculture

Soil Information:

- **Texture:** silty clay loam
- **Hydric:** N

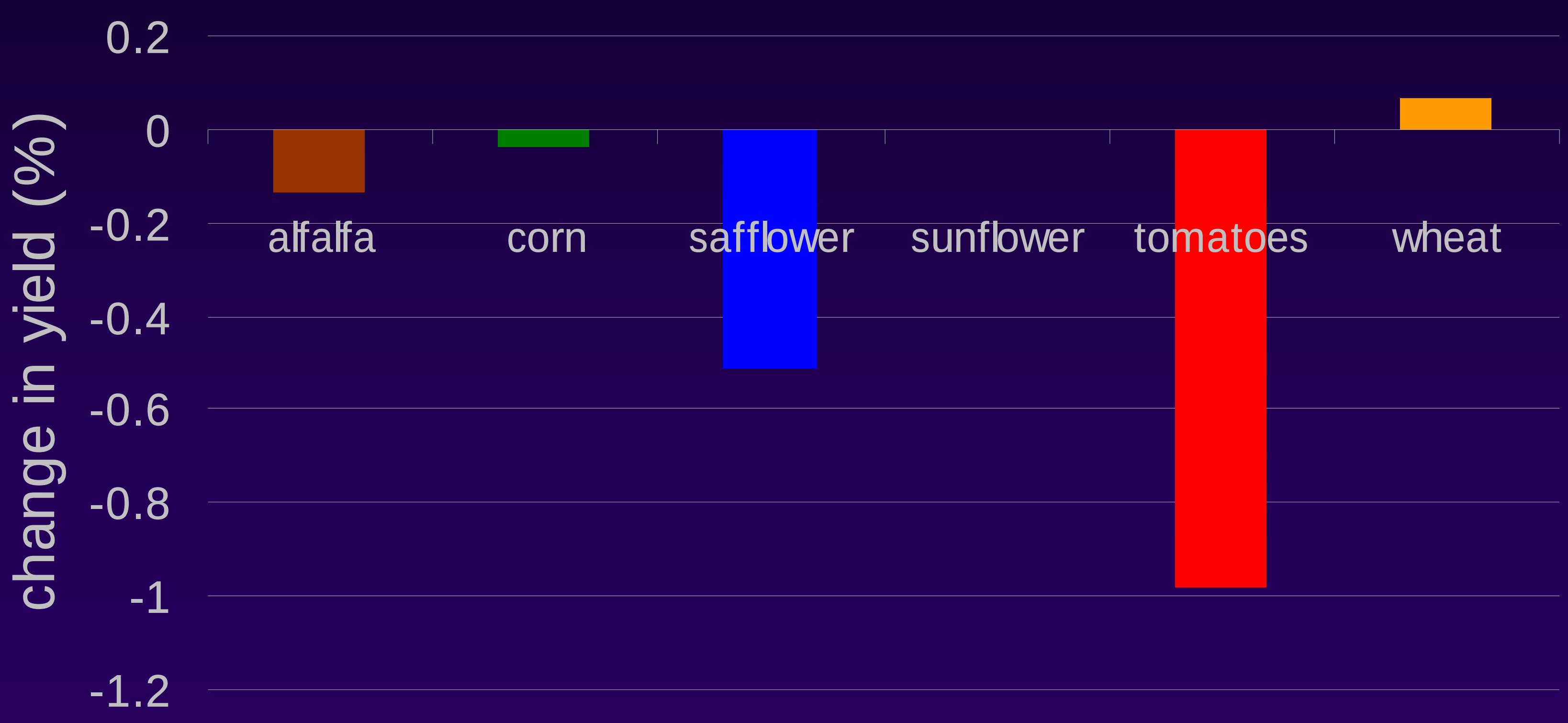
Management History:

- **Historic:** Upland Non-Irrigated (pre 1970s)
- **70's - 90's:** Non-Irrigated: corn-soybean,Intensive Tillage, CRP: None
- **Current:** Non-Irrigated: corn-soybean,Intensive Tillage,
- **Report Period:** Non-Irrigated: corn-soybean,No Till Tillage,

See Also

- NRCS Energy Estimator for Tillage
- NREL Agroecosystems
- CASMGS Consortium for Agricultural Soils Mitigation of Greenhouse Gases
- ARS Research
- U.S. Agriculture & Forestry Greenhouse Gas Inventory
- Greenhouse Gas Reporting Guidelines
- Greenhouse Gas Guidance for FARMS and FORESTS
- Draft 1605b Technical Guidelines
- 1605b Voluntary Reporting Program

Results: conventional to reduced tillage – change in yield



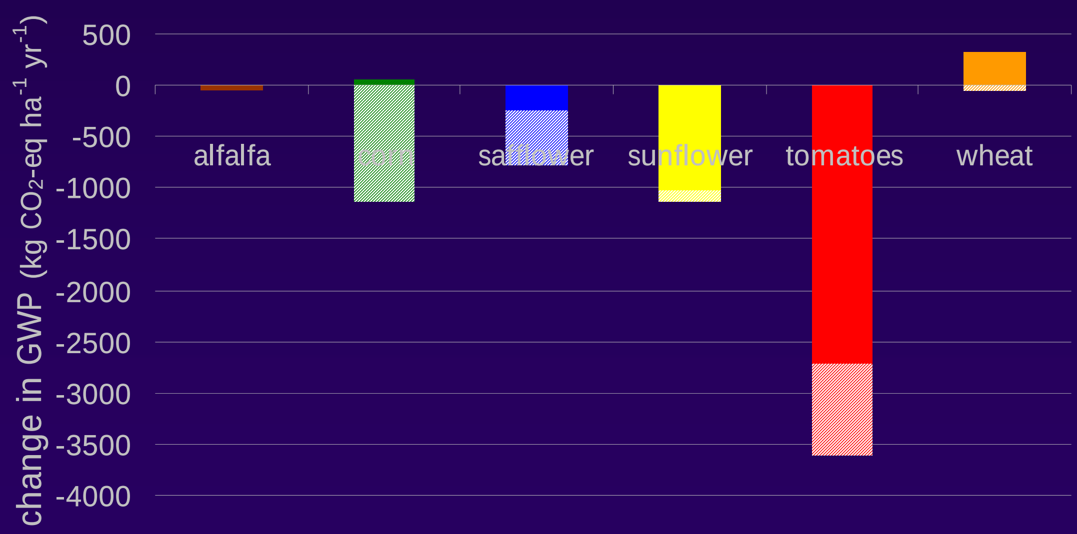
Results: conventional to reduced tillage – GHG difference

total change:

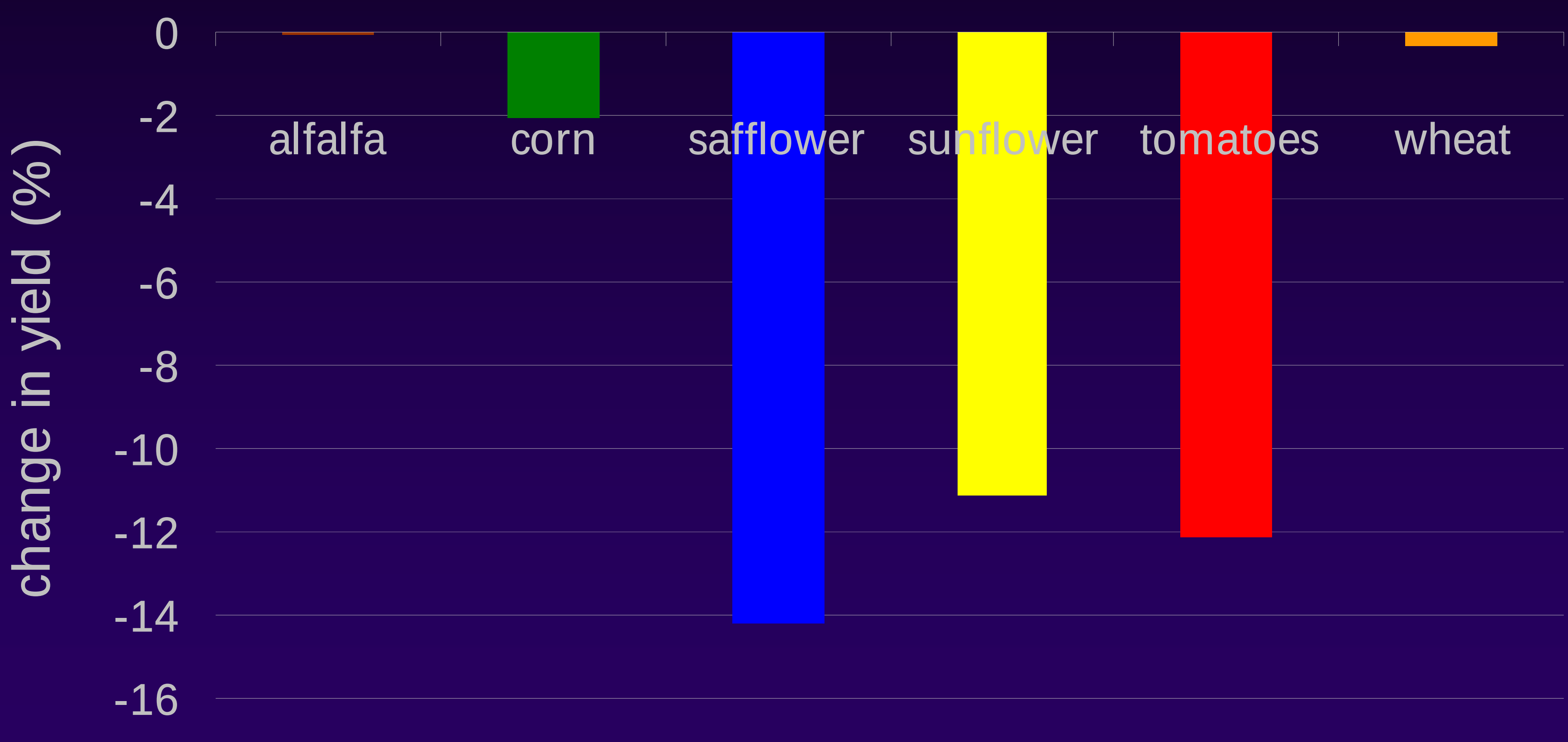
contribution of separate gases:

contribution of CO_2

contribution of N_2O

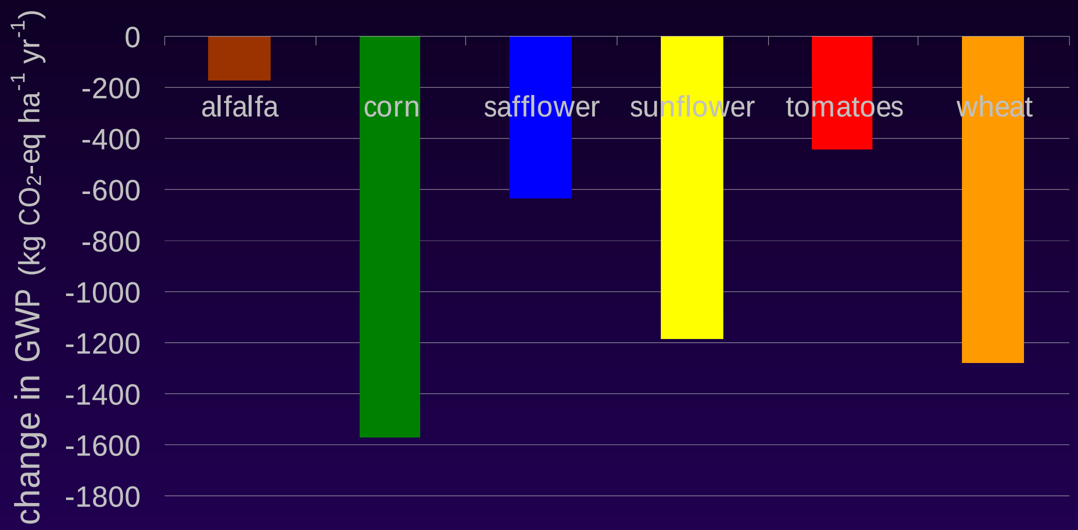


Results: conventional to low input – change in yield



Results: conventional to low input – GHG difference

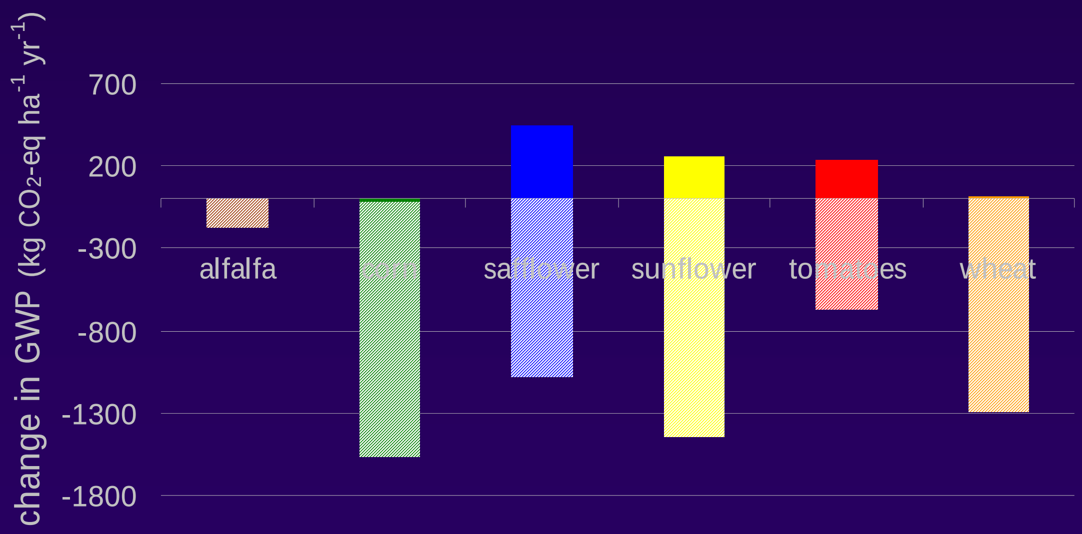
total change:



contribution of separate gases:

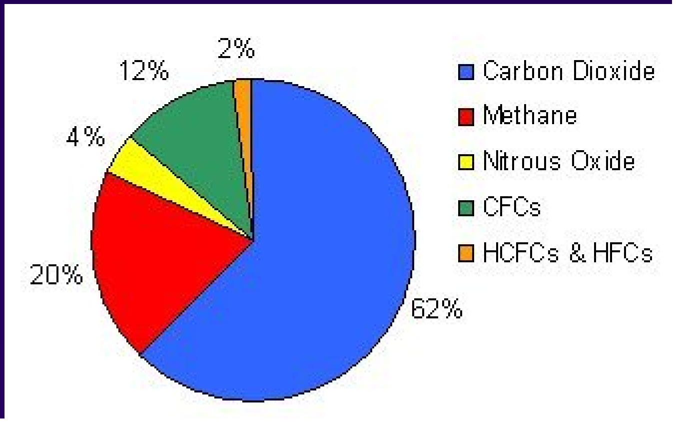
contribution of CO_2

contribution of N_2O



Introduction

- There's many GHGs
  - Water vapor
    - Human activity does not affect water vapor concentrations globally
  - Biogenic
    - CO_2, N_2O, CH_4
  - Non-biogenic
    - Fluorinated gases used in fire extinguishers and refrigerators
      - SF_6, HFC-23, Perfluorocarbon



Introduction

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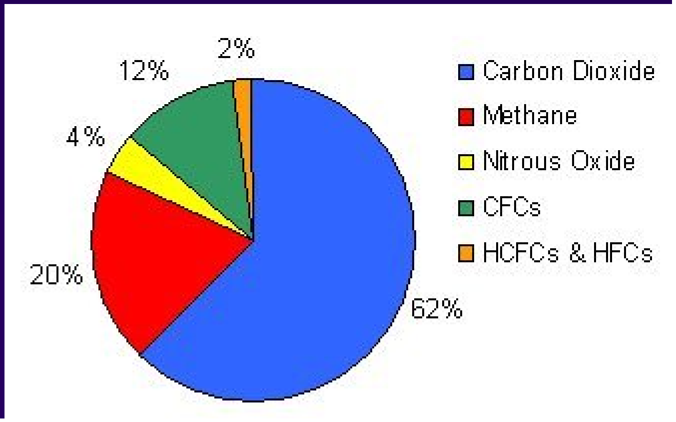
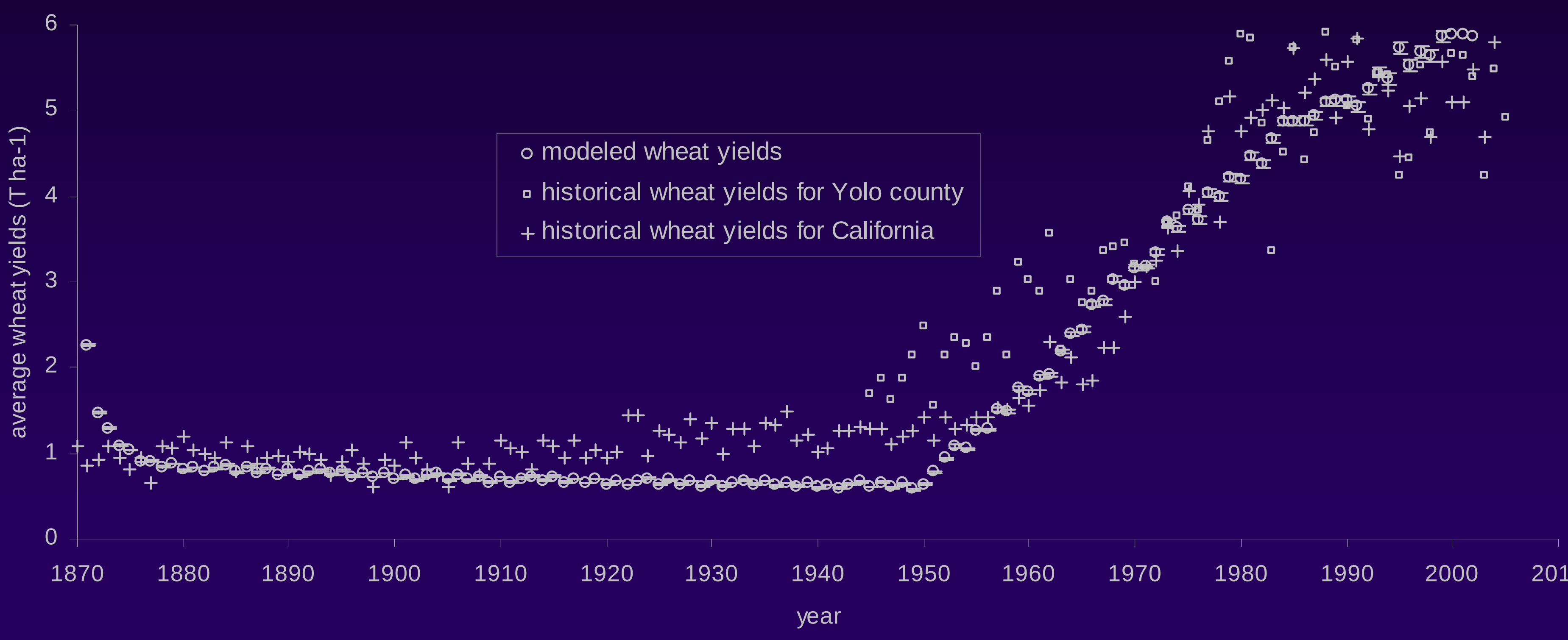
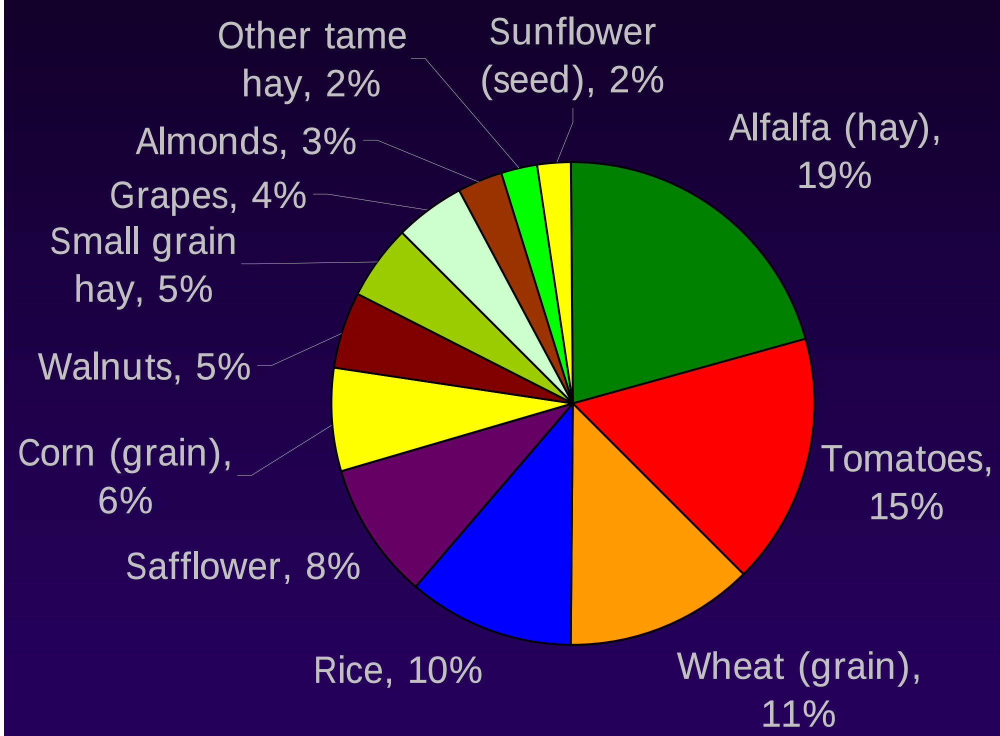


Validation: historical yields



Results: Yolo county

5 main crops (no rice) in typical rotations



USDA 2002 Census